APPENDIX IIIB:

SHRINKAGE LIMIT TEST

1. DEFINITION. The shrinkage limit of a soil is the water content, expressed as a percentage of the weight of the oven-dried soil, at which further loss in moisture will not cause a decrease in its volume. As part of the shrinkage limit test, the shrinkage ratio, R, and linear shrinkage, L_s, are also usually determined. The shrinkage ratio is defined as the ratio between a given volume change and the corresponding change in water content above the shrinkage limit. The linear shrinkage is defined as the decrease in one dimension of a soil mass, expressed as a percentage of the original dimension, when the water content is reduced from a given value to the shrinkage limit.

2. APPARATUS. The apparatus should consist of the following:

a. Evaporating dish; a porcelain evaporating dish approximately 4-1/2 in. in diameter is recommended,

b. Shrinkage dish; a circular porcelain or monel metal dish 1-3/4 in. in diameter and 1/2 in. in height is recommended.

c. Glass cup, about 2 in. in diameter and about 1 in. in height with the top rim ground smooth and flat.

d. Glass plate, 3 in. by 3 in. by 1/16 in. fitted with three metal prongs for immersing the soil pat in mercury as shown in Figure 1.

e. Mercury, sufficient to fill the glass cup to overflowing.

f. Spatula, having a blade about 4 in. long and about 3/4 in. wide.

g. Steel straightedge.

h. Balances, (1) sensitive to 0.01g, and (2) sensitive to 0.1 g.

i. Oven (see Appendix I, WATER CONTENT - GENERAL).

3. PREPARATXON OF MATERIAL. Approximately 30 g of soil shall be obtained from the thoroughly mixed portion of the material passing the No. 40 sieve. The material to be used in the test should be prepared in

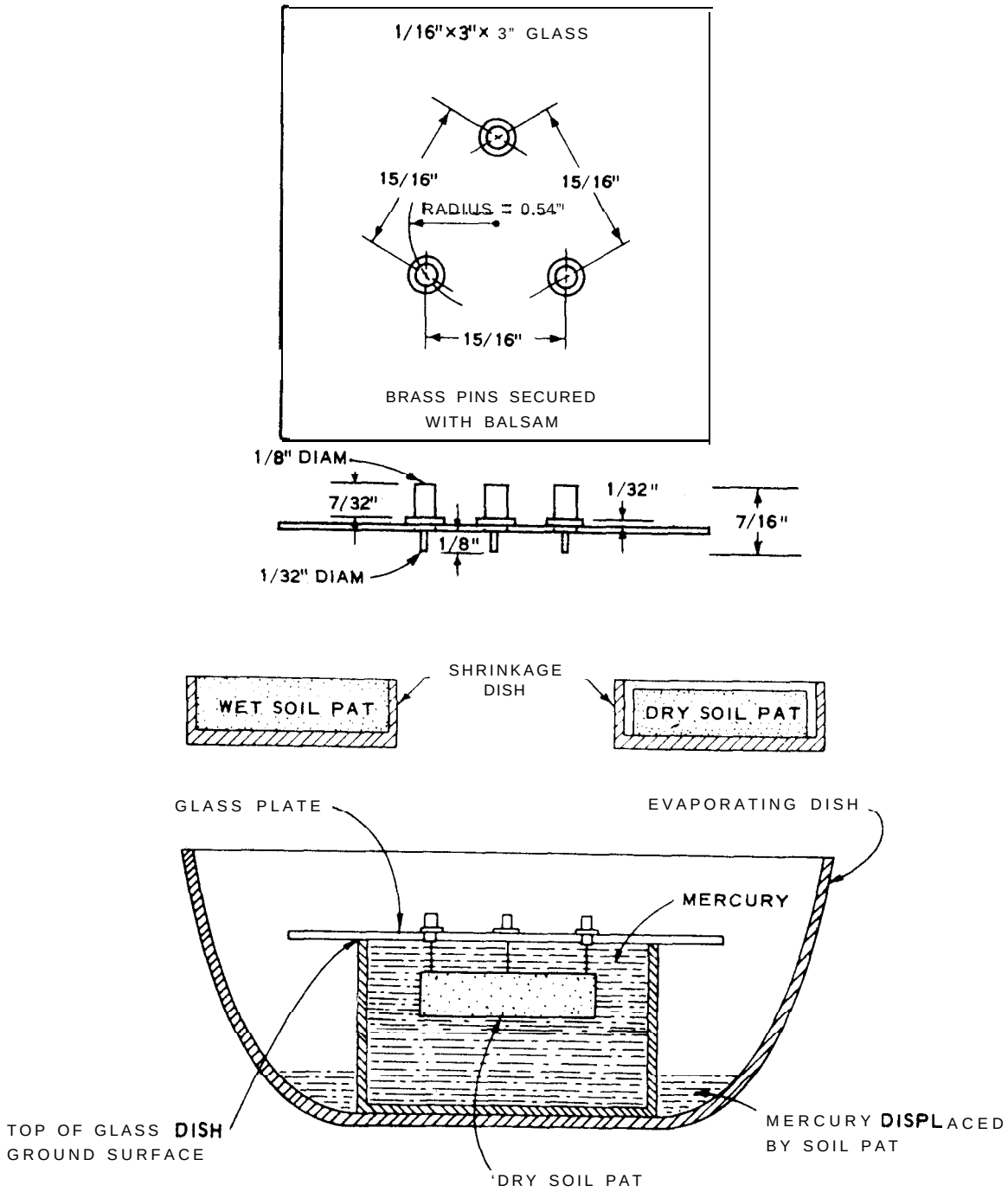

Figure 1. Apparatus for determining the volume of dry soil pat of shrinkage limit test

the same manner as that described for the liquid limit test.

4. PROCEDURE. The procedure shall consist of the following steps:

a. Record all identifying information for the specimen on a data sheet; see Plate IIIB-1 for suggested form.

b. Place the specimen in the evaporating dish and mix it thoroughly with distilled water. The amount of water added shall be sufficient to make the soil wet enough to be readily worked into the shrinkage dish without inclusion of air bubbles. The amount of water required to give friable soils the desired consistency is equal to or slightly greater than the liquid limit; the amount necessary to give plastic soils the desired consistency may exceed the liquid limit as much as 10 percent.

c. Coat the inside surface of the shrinkage dish with a thin layer of petroleum jelly or similar compound to prevent the soil from adhering to the dish. Place an amount of the wetted soil equal to about one-third the volume of the dish in the center of the dish and tap the dish on a firm surface, causing the soil to flow to the outer edges, Continue tapping the dish until all air bubbles are eliminated from the soil. Repeat this step for two more layers. The final layer shall fill the dish completely, with some excess soil allowed to stand above the rim of the dish. Strike off the excess soil with a straightedge and remove all soil adhering to the outside of the dish.

d. Weigh the full dish of soil immediately and record the weight on the data sheet as the weight of dish and wet soil. Allow the soil pat to air-dry until a definite color change takes place and then oven-dry it to a constant weight, Record the oven-dried weight as the weight of the dish and dry soil. Determine and record the weight of the empty dish.

e. Determine the volume of the shrinkage dish by filling the dish to overflowing with mercury,† removing the excess by pressing a glass

† Caution should be exercised in handling mercury. Mercury may have toxic effects, particularly if spilled on the floor in areas without good ventilation. See paragraph 7, HANDLING OF MERCURY.

plate firmly over the top of the dish, and weighing the amount of mercury required to completely fill the dish. The weight of the mercury divided by its density (13.53 g per cc) equals the volume of the inside of the shrinkage dish. Record the volume of the shrinkage dish, which is equal to the volume of the wet soil pat.

f. Place the glass cup in the evaporating dish and fill it with mercury to overflowing. Remove the excess mercury by placing the glass plate with the three metal prongs firmly over the cup; take care not to trap air under the plate. Empty the excess mercury from the evaporating dish and remove all mercury adhering to both the glass cup and the evaporating dish with a brush.

g. Determine the volume of the soil pat by immersing the pat in the mercury contained in the cup, using the glass plate with the three metal prongs as shown in Figure 1. Take care not to trap air under the soil pat or glass plate. Determine the weight of the displaced mercury and compute its volume, as indicated in step e above, and record it as the volume of the dry soil pat.

h. Record all information pertaining to the soil specimen such as weights, volumes, etc., on the data sheet, Plate IIIB-1.

5. COMPUTATIONS. a. Water Content. The water content, w, of the soil at the time it was placed in the shrinkage dish is determined as follows:

$$w = \frac{W_w}{W_s} \times 100$$

where w_w = weight of water in g, obtained by subtracting the weight of the shrinkage dish plus dry soil from the weight of the dish plus wet soil

W_s = weight of oven-dried soil in g, obtained by subtracting the weight of the shrinkage dish from the weight of the dish plus dry soil

b. Shrinkage Limit. The shrinkage limit, SL, is calculated as follows:

$$SL = w - \left(\frac{V - V_s}{W_s} \times 100 \right)$$

where SL = shrinkage limit

w = water content of wet soil pat when placed in shrinkage dish, expressed as a percentage of the weight of oven-dried soil (see paragraph a)

V = volume of wet soil pat, cc

$V_s = \frac{\text{weight of displaced mercury in evaporating dish}}{\text{specific gravity of mercury (13.53 g per cc)}}$ = volume of oven-dried soil pat, cc

W_s = weight of oven-dried soil pat, g

c. Shrinkage Ratio, The shrinkage ratio, R, shall be determined by the following formula:

$$R = \frac{W_s}{V_s}$$

where W_s and V_s are the same as given in paragraph b.

d. Linear Shrinkage. The linear shrinkage, L_s, shall be determined by the following formula:

$$L_s = 100 \left(1 - \sqrt[3]{\frac{100}{C + 100}} \right)$$

where c = volumetric change from a given water content, w (usually the liquid limit)

$c = (w - SL) R$

6. POSSIBLE ERRORS. Besides errors in the preparation of soil mixtures given in paragraph 4a of Appendix III, LIQUID AND PLASTIC LIMITS, following are possible errors that would cause inaccurate determinations of shrinkage limit:

a. Inside of shrinkage dish not lubricated. If the soil adheres to the shrinkage dish, the soil pat may crack during drying.

b. Air bubbles included in soil pat.

c. Soil pat dried too rapidly. To prevent the soil pat from cracking, it should be dried slowly, first in the humid room and then in the air of the laboratory, until a definite change in color is noted. Only then should it be placed in the oven.

d. Air bubbles trapped beneath soil pat or glass plate when immersing pat in mercury.

7. HANDLING OF MERCURY.* a. Properties. Mercury is an odorless silver-white liquid at normal temperature and pressure. Mercury has the property of forming amalgams with most metals, with the exception of platinum and iron. It is highly volatile, vaporizing at room temperature to form vapors that are highly toxic. Mercury has a specific gravity of 13.6, a boiling point of 356.9 C, and a freezing point of -38.9 C.

b. Health Hazards. The air concentration of mercury vapor corresponding to the equilibrium vapor pressure at room temperature (20 C) is approximately 20 mg per cu m, or 200 times the safe concentration of 0.1 mg per cu m for continuous exposure (8 hr per day, 5 days per week); safe concentrations for shorter periods have not been proposed. Inhalation of mercury vapor of concentrations greater than 0.1 mg per cu m *over* a long period of time can cause chronic poisoning. The initial symptoms of poisoning may include gingivitis, digestive disturbance, fine tremor of the extremities, irritability, excessive emotional response, and

* "Mercury" Data Sheet 203, National Safety Council, 425 N. Michigan Ave., Chicago? Ill. 60611.

exaggerated salivation. These symptoms may increase in severity and may result in permanent disability. Exposure to concentrations far greater than the maximum allowable concentration for short periods of time can cause acute illness. The exact nature, concentration, and duration of exposure determine the type and severity of symptoms, Although inhalation of mercury vapor is by far the greatest avenue of entry to the body, ingestion and absorption through the skin are also possible

c. Use. Whenever possible, use of mercury for teat purposes should be avoided. Personnel working in an area where mercury is used should be made aware of its hazards.

d. Detection. Direct reading units for determining the concentration of mercury vapor are available from the following sources:

Mine Safety Appliances Company
211 N. Braddock Ave.
Pittsburgh, Pennsylvania 15208

Union Industrial Equipment Corporation (UNICO)
150 Cove St.
Fall River, Massachusetts 02720

Acton Associates
1180 Raymond Blvd.
Newark, New Jersey 07102

Beckman Instruments, Inc.
2500 Harbor Blvd.
Fullerton, California 92634

e. Handling. The precautions listed below should be observed when handling mercury.

(1) Mercury shouldnot be heated without elaborate control because of the rapid increase of vapor pressure with increase in temperature.

(2) Eating and smoking should not be permitted in areas where mercury is handled. Hands should be thoroughly washed after handling mercury.

(3) If clothing becomes contaminated, a change of clothes should be available.

(4) Respiratory protection should be available where there is a possibility of contamination.

(5) All laboratories handling mercury should have a precise plan to be followed in decontamination after a mercury spill. Some general proposals are:

(a) Maximum general exhaust ventilation and local exhaust should be effected. Windows should be opened.

(b) A vacuum flask or a vacuum cleaner designed for removal of mercury should be put into service immediately to recover the mercury.

(c) The area should be decontaminated by treating with flowers of sulfur or other decontaminant.

(d) Effectiveness of decontamination should be verified with a mercury vapor detector.

f. Facilities. In facilities where mercury is handled the measures listed below should be taken.

(1) Floors of areas should be free of cracks and the inter - section of the wall and floor should be fitted with a cove,

(2) Recirculation of air in room should be discouraged because of the possibility of buildup of mercury vapor.

(3) Mercurymanometers should be provided with traps to ensure that there will be no spillage of mercury into a process line or into room.

(4) Precision equipment should be removed from areas where contamination with mercury is possible.

g. Transportation and Storage. Whentransporting and storing mercury the following precautions should be taken.

(1) Mercury containers should be placed in a tray when transported within the laboratory; metal or continuous type (nonwelded) plastic containers are preferable to glass ones.

(2) Mercury containers should be stored in pans that will contain any spillage.

SHRINKAGE LIMIT TEST

Date _____

Project _____

Boring No. _____

Sample or Specimen No.					
Shrinkage Dish No.					
Weight in grams: Dish plus wet soil					
Dish plus dry soil					
Water	W_w				
Shrinkage dish					
Dry soil	W_s				
Displaced mercury + evaporating dish					
Evaporating dish					
Displaced mercury					
Volume in cc: Shrinkage dish (wet soil pat)	V				
Volume of dry soil	V_s				
$V - V_s$					
$\frac{V - V_s}{W_s} \times 100$					
Water content = $\frac{W_w}{W_s} \times 100$	w	%	%	%	%
Shrinkage limit	SL				
Shrinkage ratio	R				

$$V_s = \frac{\text{weight of displaced mercury}}{\text{specific gravity of mercury (13.53 g/cc)}}$$

$$SL = \text{Water content of wet soil pat} - \left(\frac{\text{volume of wet soil pat - volume of oven-dry soil pat}}{\text{wt of oven-dry soil pat}}\right)$$

$$= w - \left(\frac{V - V_s}{W_s} \times 100\right)$$

$$R = \frac{\text{wt of oven-dry soil pat}}{\text{volume of oven-dry soil pat}} = \frac{W_s}{V_s}$$

Classification: _____

_____

Remarks _____

_____

Technician _____ Computed by _____ Checked by _____

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PLATE IIIB-1